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Dicalcium Phosphate as a Mineral Supplement for Dairy Cows

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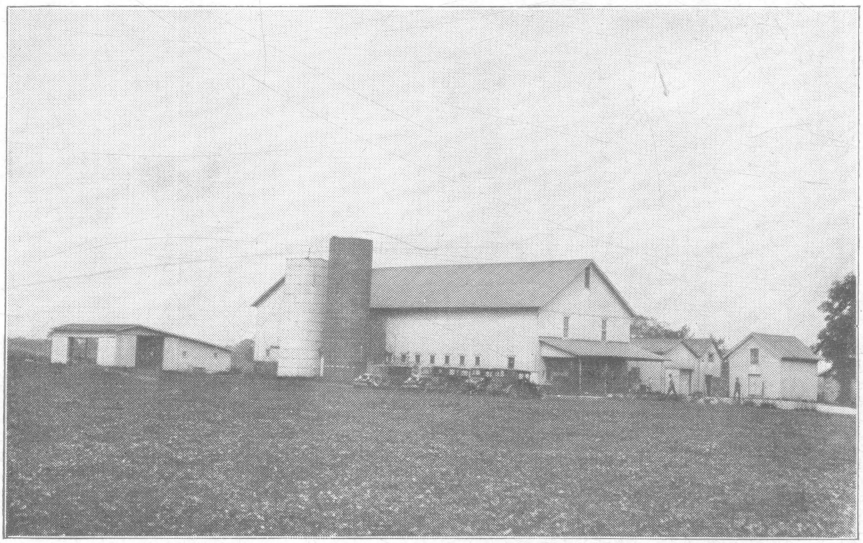


Trumbull County Experiment Farm barn where the experiment was conducted

DICALCIUM PHOSPHATE AS A MINERAL SUPPLEMENT FOR DAIRY COWS

C. C. HAYDEN, C. F. MONROE, AND C. H. CRAWFORD

INTRODUCTION

The practice of feeding mineral supplements to dairy cows has become quite general during the last few years. This is indicated by the extensive sale of commercial mineral mixtures, the common use of such substances as steamed bone meal and ground limestone in home-mixed rations, and the prevalence of ready-mixed grain feeds containing "minerals".

Apparently the belief, which has become general, that mineral supplements to the dairy ration are necessary has grown from the following: 1, outstanding benefits obtained by feeding minerals to hogs, chickens, and experimental rats; 2, favorable results obtained by feeding minerals to cattle on rations markedly deficient in calcium or phosphorus; 3, wide publicity given the results of some metabolism tests which have shown milking cows to be losing calcium and phosphorus at a rapid rate; 4, a few rather favorable results obtained in metabolism tests where mineral supplements were fed; 5, rumors that minerals aid in preventing or overcoming the ravages of abortion disease and sterility.

Prominent authorities still differ as to the conditions under which addition of minerals to the dairy ration is necessary. The general opinion seems to be that, inasmuch as they apparently do no harm and may do some good, their use is to be recommended until more is known about the requirements of the dairy cow for such substances and her ability to utilize them. Therefore, mineral supplements are regarded by many as insurance against deficiencies which may occur. However, as it costs to carry insurance, the returns should, in the long run, justify the expense. The object of the experiment here reported was to obtain additional information on this subject.

REVIEW OF OTHER WORK

METABOLISM EXPERIMENTS

Mineral metabolism experiments by Forbes and co-workers (1), (2), (3) showed heavy losses of calcium and phosphorus from the bodies of milking cows. According to them, "The largest milk

production with which there was calcium retention was 9.98 pounds daily." They fed as supplements such substances as calcium lactate, calcium chloride, calcium carbonate, and precipitated bone phosphate. As a result of their work, these investigators (3) made the following statement:" The advantage to be derived from the feeding of mineral supplements seems to us doubtful, but it is so easy to provide minerals in this form that the possibilities of benefit from so doing should be thoroly investigated, under conditions of practice, not only during the winter feeding but also during the season of pasturing."

Metabolism experiments reported by Hart and co-workers (4) showed that bone meal fed in connection with timothy hay reduced the mineral losses somewhat, and when fed in connection with green roughage resulted in positive calcium balances in most cases (5). They found that positive balances and the extent of mineral storage were somewhat dependent on the supply in the body of the cow when the tests started. At the Ohio Experiment Station (6) it was noted that the conditions under which the cows were kept preceding the experiment affected the mineral balances.

Miller and associates (7) fed 150 grams daily of bone meal in addition to a basal ration of clover, corn silage, and a mixture of grains to dairy cows and obtained results from which they concluded: "Supplementing with bone meal caused increased storage of calcium and phosphorus."

Balance experiments conducted by the Dairy Department of the Ohio Experiment Station (8) showed positive calcium balances at a production level of 30 pounds of milk daily. The hay used was of good quality and the experiments were conducted in the summer. Other investigators (5), (9), (10) have obtained approximately the same results. While the conditions represented by these balance experiments are not entirely comparable, evidence is furnished to the effect that mineral losses from the bodies of milking cows are not generally so extensive as indicated by the results obtained by Forbes.

Obviously, if cows can support fairly liberal milk production without losing minerals, there would seem to be little or no need for supplying extra mineral matter for this level of production. It is apparent that the short-time feeding of mineral supplements during metabolism experiments will not adequately answer the question concerning the real value of these supplements.

FEEDING TRIALS

McCandlish (11) fed eight cows steamed bone flour in a double reversal experiment which consisted of three 25-day periods. The bone meal had no marked effect on milk or butterfat production.

The Delaware Experiment Station (12) reported an experiment conducted to determine the effect of feeding finely pulverized limestone. Four fresh cows, fed limestone, were compared with four other fresh cows fed similarly, but without the limestone. Corn-soybean silage was the only roughage fed. As the dry periods preceding the freshenings had been comparatively short, the presumption was that these cows had not had an opportunity to build up very extensive mineral reserves. Under these conditions the feeding of limestone might well have been expected to show beneficial results, but no benefit was noted.

At the Arizona Experiment Station (13) 16 cows, divided into four groups, were fed minerals as follows: group 1, sodium phosphate; group 2, bone meal; group 3, air-slaked lime; and group 4, no mineral supplement. Alfalfa hay, a good source of calcium, was the roughage fed. The results were summarized as follows: "A tabulation of the yields of milk and butterfat did not show any advantage from feeding minerals either in quantity of production or persistency of milking. Fully as much difficulty was experienced in getting cows bred when minerals were used as when no minerals were fed."

It has been shown by Eckles, Becker, and Palmer (14) and also by Theiler, Green, and Du Toit (15) that a state of depraved appetite caused by rations low in phosphorus can be relieved by the feeding of steamed bone meal or mono-basic sodium phosphate. Emaciation, cessation of oestrum, and other conditions accompanying the mineral deficiency were remedied by such feeding. The experiments by Eckles have also shown that a mature cow fed these phosphorus-deficient rations ate 50 to 60 pounds of bone meal a year when given her free choice. As a practical recommendation, Eckles suggests that cattle be allowed access to bone meal regularly, just as they are to common salt.

Nevens (16) found that cows and heifers which had free access to bone meal and limestone consumed "almost insignificant amounts", and he concludes: "Good rations seem to satisfy calcium and phosphorus needs." The cows were receiving a good grade of legume hay, corn silage, a grain mixture of corn, oats, wheat bran, and a second protein supplement.

Lindsey and Archibald (17) fed bone meal to a herd of about 14 cows in connection with a ration rather low in mineral content. The roughage, timothy hay, was low in calcium and the grain mixture was low in phosphorus. This experiment, covering a period of four and one half years, resulted in the following statement by the authors: "The advantage to be gained from the practice of supplying lime in the form of steamed bone meal seems very slight." The data also indicated that the phosphorus of the bone meal had but little effect.

Meigs and Woodward (18) obtained a marked increase in milk during the first lactation period following the feeding of disodium phosphate to a herd of cows. They did not obtain the same results with cows fed more liberally for advanced registry. Meigs (19) also brought about an improvement over a timothy hay ration by adding calcium carbonate, but the results were not as good as with a ration containing alfalfa hay.

Hart, Steenbock, Humphrey, and Hulce (20) found that the addition of calcium salts to rations extremely low in lime permitted normal reproduction, which was not the case when the supplements were omitted.

Reed and Huffman (21) have shown that feeding high grade, raw rock phosphate, especially prepared for livestock, had a detrimental effect on the health of the animals. They concluded that this mineral should not be fed to cattle. Later reports (22) indicate that the injurious effects were due to the fluorine content of the rock phosphate. Steamed bone meal did not prove toxic.

From the evidence submitted it is apparent that, under certain conditions, minerals fed in the inorganic form are beneficial to dairy cows. However, these conditions are not considered even moderately favorable for milk production. The supplementing of good rations with such minerals has failed to show any marked benefits. The use of mineral supplements to correct rations which have led to nutritional failure is quite different from their use to improve rations which have seemingly given good results. If such supplements fail to give apparent benefit when fed with reasonably good rations, it would seem that their general use is not justified.

It was recognized that a practical test of the value of mineral supplements for general use should be made under conditions consistent with continuous, or long-time, economical milk production. The experiment here reported was planned to meet this requirement.

EXPERIMENT

PLAN

This experiment was conducted on the Trumbull County Experiment Farm, located in the northeastern part of Ohio, a section generally deficient in lime. However, on this farm a part of the pasture and the land on which feeds were grown was limed and fertilized. The experiment was started January 1, 1923, and terminated December 1, 1928, covering a period of 5 years and 11 months. The conditions closely approximated those which can be attained by the average dairyman. They did not represent the ideal nor the best conditions as we understand them, but rather a compromise between the best and the poorest conditions found on many farms.

COWS USED

Twenty-nine cows in all were used in this work. They were purebred or high-grade Holstein-Friesians, with the exception of one Jersey cow. At the beginning of the experiment the herd, which usually consists of 12 to 18 cows, was divided into two groups approximately equal in milk production. As the heifers raised reached the age of one year they were allotted to the two groups.

CARE AND FEEDING

Both groups were fed and cared for alike, except that the grain mixture fed to one group contained 2 per cent of dicalcium phosphate. The details of the feeding and management varied somewhat during the course of the experiment, but the same variations occurred in both groups. The cows were fed liberally. The average annual production was above 9,000 pounds of 4 per cent milk and the return over feed cost was very satisfactory.

Hay and corn silage were fed at the rate of approximately 1 pound of hay and 3½ pounds silage per 100 pounds of live weight, and grain largely according to the productive capacity and condition of the various cows. The hay usually consisted of timothy and clover mixed, but on a few occasions some legume hay was fed. The grain mixture varied somewhat, but usually was about as follows: 200 pounds of corn, 200 pounds of oats, 200 pounds of wheat bran, 100 pounds of linseed oilmeal, and 100 pounds of cottonseed meal.

The herd was on pasture each year from May until October and was fed varying amounts of grain according to the condition of the

pasture. Hay was fed in late summer when the pasture was short and in each of the last two summers soybeans were fed as a soiling crop for about 45 days.

The cows were fed and milked by hand twice daily.

MINERAL USED

The entire supply of mineral came from one company which described it as follows: "Dicalcium phosphate is manufactured by precipitating the phosphate extracted from a very high grade of bone by the use of high grade chemical lime. It is made in connection with the manufacture of pure food gelatin." Analyses showed that it contained 38.6 per cent of phosphoric acid (P_2O_5), 34 per cent of lime (CaO), 25.2 per cent of volatile organic matter, and small amounts of other substances such as iron, aluminum, sulphur, chloride, magnesium, etc. In appearance, it resembled flour and was originally called "Banner Bone Flour". It was mixed with the grain at the rate of 2 pounds of mineral to 98 pounds of grain. Its cost was six cents per pound.

TABLE 1.—Average Daily Feed Consumption per Cow for the Entire Experiment

	Grain	Hay	Silage	Pasture per lactation
	Lb.	*Lb.*	*Lb.*	*Days*
Mineral group	10.6	10.7	25.4	117.9
Non-mineral group	10.5	10.1	26.0	137.4

When the dicalcium phosphate was first added it seemed to make the grain mixture slightly less palatable; however, the cows soon became accustomed to it. There was no marked difference in the consumption of the mineral and non-mineral rations. This is shown in Table 1.

RESULTS

MILK PRODUCTION

In long-time experiments, such as this, where the groups are not reversed and where certain variable factors enter to prevent keeping the groups equally balanced in numbers and production, it is difficult to make a direct and accurate comparison of the effects of the minerals on the production of milk. Because of this, certain correction factors have been applied and the data are presented in the following ways:

1.—The total actual production of milk by the two groups is compared.

2.—The total yields of milk are corrected to a 4 per cent fat basis by the Gaines formula and compared.

3.—The yields of milk during the first 7 months of the lactation periods are compared, omitting those periods that do not contain the first full 7 months.

4.—The yields of milk are calculated to a mature age basis by the Clark factors and compared.

5.—The yields of milk by original cows in the two groups before and during the experiment are compared.

6.—The yields of milk during the first and second lactation periods of heifers are compared.

1. TOTAL PRODUCTION

A study of the effect of the mineral supplement on milk production does not reveal any marked benefit. Table 2 gives the average daily production of the cows in the mineral and non-mineral groups. The actual milk yields for all cows by lactation periods during the entire experiment are given in Table 9 (Appendix). It will be noted that there was a large amount of variation in the length of the lactation periods listed. The longer periods were due to difficulty in getting cows to conceive, and the shorter ones were parts of periods such as occurred at the beginning and close of the experiment.

TABLE 2.—Average Actual Daily Production of Milk and Fat

	Age	Days in milk	Daily milk	Daily fat
	Years	*No.*	*Lb.*	*Lb.*
Mineral group	5.4	340.8	30.54	1.039
Non-mineral group	5.03	363.5	29.73	1.026
Differences in favor of mineral group	0.37	−22.7	0.81	0.013

On the basis of actual production, the average daily milk yield per cow on the mineral ration was 30.54 pounds, with 1.039 pounds of fat; on the non-mineral ration 29.73 pounds of milk, with 1.026 pounds of fat. The cows receiving the minerals averaged 0.81 pound of milk and 0.013 pound of fat more per day than the non-mineral group. Fifty periods (17,039 days) by 16 mineral cows and 32 periods (11,634 days) by 13 non-mineral cows were used in determining these averages.

On this basis, the mineral ration would appear to be slightly the better. However, the difference is small and is far from being significant statistically.

2. TOTAL PRODUCTION CORRECTED TO 4 PER CENT FAT BASIS

The true measure of the efficiency of a ration is the amount of total nutrients produced in the milk. Therefore, a better comparison may be made if the milk from both lots is reduced to the same energy value per unit. For this purpose the Gaines formula has been used [Fat corrected milk (F. C. M.) $= 15$ fat $+ 0.4$ milk]. As stated at the beginning, the cows were purebred or high-grade Holstein-Friesians and therefore produced milk testing under 4 per cent fat. Applying the correction formula reduced the amount of milk for both groups. Computed in this way, the average daily yields of 4 per cent fat milk were 27.81 pounds for the mineral and 27.28 pounds for the non-mineral cows. The difference, 0.53 pound daily, is still in favor of the mineral-fed cows. A slightly greater reduction occurred in the average of the mineral group than in that of the non-mineral group. This comparison shows a little less difference in favor of the mineral-fed cows than before the correction was made.

3. CORRECTED FOR LENGTH OF LACTATIONS

In order to compare the milk productions on the basis of standard length lactations, only those periods containing the first seven clear calendar months after freshening were used. By this method, it is possible to use actual production figures, rather than calculated ones, as is sometimes done.

Limiting the data to the first 7 months after calving eliminates 5 parts of lactations from the mineral group and 3 parts of lactations from the non-mineral group. These parts of periods occurred at the beginning and close of the experiment. The effect of discarding these parts and using the other full periods differed in the two groups. The average daily yield of the mineral group was lowered to 26.6 and that of the non-mineral group raised to 27.9 pounds. That this result favored the non-mineral group can be attributed to the fact that most of the parts of lactations dropped from the mineral group were at the beginning, while most of those dropped from the non-mineral group were at the end of lactation.

By comparing the production during the first 7 months of lactation periods with the full time of the same periods, the daily average of the mineral group was raised to 31.8 and of the non-

mineral group to 33.3 pounds as shown in Table 3. The difference becomes 1.5 pounds daily in favor of the non-mineral group. Part of this gain by the non-mineral group may be explained by stating that the average lactation period in the non-mineral group was longer than in the other group and pregnancy may have had less effect on milk flow. However, the change in balance to favor the non-mineral group was caused by eliminating the partial periods and not by equalizing the lactation periods to the basis of first-seven-months following calving.

TABLE 3.—Comparison of 7 Months' Periods with Full-time Lactations

	Mineral group Daily F. C. M.	Non-mineral group Daily F. C. M.
	Lb.	*Lb.*
7-month periods	31.8	33.3
Full time periods	26.8	27.9

4. CORRECTED FOR AGE

The average of the cows at the beginning of the various lactations was 5.2 years for the mineral group and 4.9 years for the non-mineral group. It is evident that age corrections would favor the non-mineral group. The age correction factors, given by Clark (24), were applied in obtaining the data presented in Table 4.

TABLE 4.—The Effect of Applying an Age Correction on the Production of 4 Per Cent Milk During the First Seven Months

	Age	Daily production	Corrected
	Yr.	*Lb.*	*Lb.*
Mineral group	5.2	31.8	37.3 ± .801
Non-mineral group	4.9	33.3	39.8 ± .782

On this basis the average daily milk production for the 7-month periods was 37.3 pounds for the mineral group and 39.8 pounds for the non-mineral group, a difference of 2.5 pounds in favor of the non-mineral group. Even this difference is not mathematically significant. Since the probable error of the difference is 1.12 pounds the difference would have to be 3.55 pounds to be considered really in favor of the non-mineral cows. Therefore, it cannot be said that feeding minerals was detrimental. The detailed figures for this method of comparing the results are given in Table 10 (Appendix).

Probably this last comparison, in which corrections have been made for quality of milk, length of lactation, and age of animals, is the most accurate method of interpreting the data on milk production.

OTHER COMPARISONS

Two other comparisons which throw additional light on the problem may be made.

5. PERIODS BEFORE AND AFTER FEEDING MINERALS COMPARED

In the foregoing estimation of the value of dicalcium phosphate in the ration, it has been assumed that the average producing ability of the two groups was approximately equivalent. As the groups were not reversed during the experiment a direct comparison of the milk yields of the same animals on the different rations has not been possible for the entire groups. However, a direct comparison may be made of data from a few of the cows that were present in the herd at the start of the experiment.

Records of production made before the experiment by six cows of the original group of mineral-fed cows were available for comparison with their records after feeding minerals. Similar records were also available for a like number in the non-mineral group. The production of each cow during the first 7 months of the last lactation before and the first lactation after the experiment started was used in making the comparison. The figures are shown in Table 5. The milk produced was corrected for quality and age of animal. For more complete data see Table 11 (Appendix).

TABLE 5.—Showing Production Before and After Feeding Dicalcium Phosphate (F. C. M., 7-month periods, mature age)

Group	Before	After	Gain
	Lb.	*Lb.*	*Per cent*
Mineral group of 6 cows	26.5	29.8	12.4
Non-mineral group of 6 cows	27.0	32.9	21.8

Table 5 shows that both groups increased in production after the experiment started. Doubtless this was due to better feeding. The average daily increase by the six cows in the mineral group was 3.3 pounds or 12.4 per cent, and by the six cows in the non-mineral group 5.9 pounds, or 21.8 per cent.

Much the same results were shown when the full lactations were used and when age corrections were not made. The cows receiving the dicalcium phosphate made a considerable increase, but the cows not receiving it made a greater increase under the same conditions.

6. FIRST AND SECOND LACTATIONS OF HEIFERS COMPARED

It is commonly held that small deficiencies in the ration may not show up in milk production during the first lactation period, but appear in subsequent periods after possible reserve stores of materials in the body have been used up. It was possible to make this comparison with ten heifers, five from the mineral group and five from the non-mineral group. The data are presented in Table 6. For more complete data see Table 12 (Appendix).

TABLE 6.—Comparing the First and Second Lactations of Heifers (F. C. M., 7-month periods)

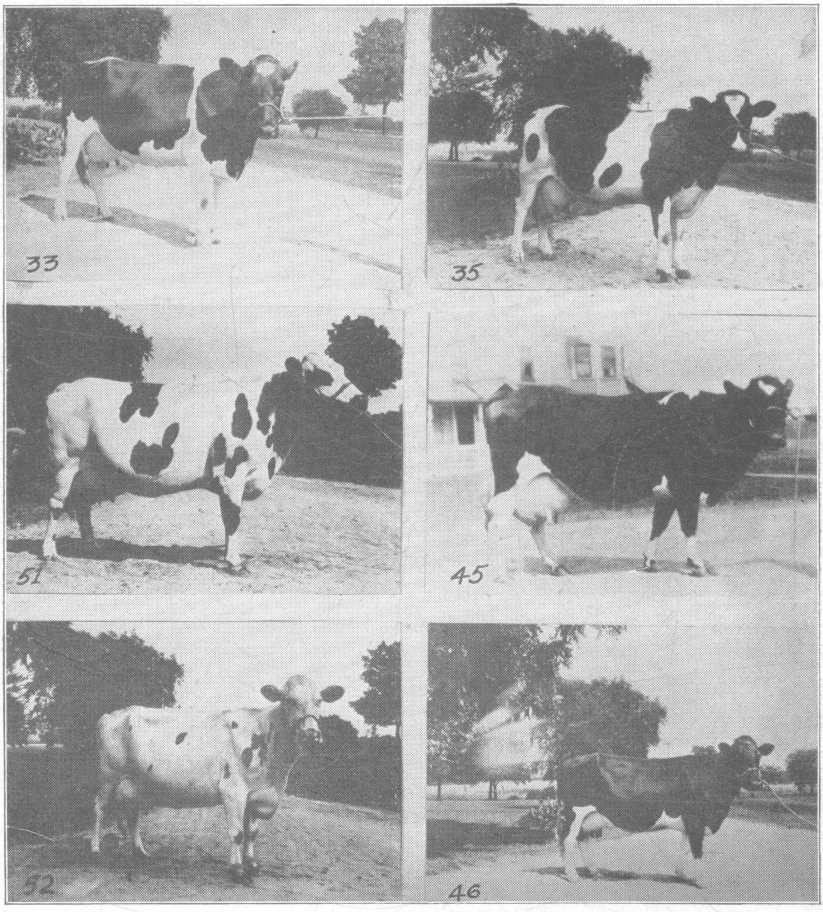
	First lactation	Second lactation	Gain
	Lb.	*Lb.*	*Per cent*
Mineral group	27.6	35.3	27.9
Non-mineral group	26.0	34.0	30.8

The heifers receiving minerals made a 27.9 per cent increase in milk in their second over their first lactations; while the heifers not receiving minerals made a 30.8 per cent increase. It is evident from these figures that the minerals had no beneficial effect on milk production.

SUMMARY OF MILK PRODUCTION

The data for milk production indicate that there was no increase that could be attributed to the feeding of the dicalcium phosphate. While the total actual production of milk and fat was slightly greater in the mineral group, an analysis showed that a comparison on this basis was obviously unfair. Hence the production records of the individual cows were reduced to a common basis. Corrections were made for differences in butterfat percentages, length of lactation, and age. All of these corrections affected both groups about equally. However, eliminating those periods which did not contain the first full seven months after calving favored the non-mineral ration and changed the balance.

With all records computed to 4 per cent (F. C. M.) milk at a mature age and covering the first full seven months after calving, the average daily productions were 39.8 pounds, and 37.3 pounds for the non-mineral and mineral groups, respectively. The difference of 2.5 pounds favoring the non-mineral group was not considered significant.



Representative cows from the non-mineral group

Representative cows from the mineral group

A comparison of the records of 12 cows before and after feeding the mineral supplement as well as a comparison of the first and second lactations of the heifers in the two groups also failed to show any superiority of the mineral ration.

HEALTH OF THE HERD

CONDITION OF THE COWS

The cows in both groups kept in good condition. Any difference in physical appearance which may have existed between the two groups was not sufficiently outstanding to be detected by the men in charge or by various cattlemen who visited the farm.

Calves born at mature time were uniformly thrifty, and no difference was detected between those from the two groups.

BREEDING

The statement is sometimes made that minerals assist in preventing breeding troubles. In this experiment there was a slight indication that dicalcium phosphate had some beneficial effect. The data considered in this comparison of the breeding records of the two groups included 34 lactations in the mineral group and 22 lactations in the non-mineral group. The following lactations were discarded: those followed by abortions or sterility, those where animals were sold for breeding purposes, those where cows were not due until after the close of the experiment, and those begun before the experiment started.

Table 7 gives the average breedings necessary per calf in the two groups. For individual data see Table 13 (Appendix).

TABLE 7.—Average Days in Milk, Days Dry, and Breedings per Calf

	Days in milk	Days dry	Breedings per calf
	No.	*No.*	*No.*
Mineral group	363	51	1.53
Non-mineral group	399	55	2.13

The average number of breedings per calf in the mineral group was 1.53 and in the non-mineral group 2.13. Six heifers fed minerals required 1.5 breedings; while seven heifers without minerals required 2.1 breedings. In the mineral group 88 per cent of the conceptions required one or two breedings and 12 per cent required three breedings. In the non-mineral group 59 per cent of the conceptions required one or two breedings, 27 per cent three breedings, 9 per cent four breedings, and 4 per cent six breedings. The fewer breedings in the mineral group are slightly significant from a statistical viewpoint.

DISEASES

During the course of the experiment one cow in the non-mineral group reacted to the tuberculin test. This, of course, was a matter of chance.

Abortions occurred four times in the mineral group and once in the non-mineral group. Permanent sterility occurred three times in the former and four times in the latter group. Table 8 shows the number of cases of abortions, sterility, and tuberculosis occurring in the two groups.

TABLE 8.—Cases of Abortion, Sterility, and Tuberculosis

	Mineral group	Non-mineral group
Abortion	4	1
Sterility	3	4
Tuberculosis	0	1

There were cases of retained placenta in both groups.

There is a slight indication that the dicalcium phosphate aided in the matter of conceptions, but it is evident that it did not prevent abortions, sterility, or retained placentae.

GENERAL DISCUSSION

In the experiment here described no marked benefits from feeding the mineral supplement, dicalcium phosphate, were found. These results should be taken to mean simply that the feeding of dicalcium phosphate under the conditions of this experiment contributed no improvement with respect to milk and butterfat production, nor to the general health of the cows, in so far as could be determined. It is not recommended that cows be fed dicalcium phosphate when they are receiving a good mixed or legume hay in connection with a balanced grain mixture. While such a practice would not be harmful to the cows the expense would not be justified.

The results here noted with the use of dicalcium phosphate are quite similar to those obtained by Lindsey and Archibald at the Massachusetts Experiment Station (17) previously mentioned. In their work the mineral supplement fed was steamed bone meal. This was used in connection with a ration of relatively low mineral content. While it is true that the steamed bone meal was slightly beneficial, the production on this type of ration did not justify this method of feeding. This is also in agreement with the results obtained by Meigs (19).

The general indications seem to be that too much dependence should not be placed on mineral supplements. The feeding of inorganic substances such as bone meal or dicalcium phosphate should be regarded as a protection against deficiencies which might occur, rather than as partial substitutes for good rations. On the basis of present knowledge, it appears that the best way to feed minerals is by the use of feeds rich in these substances. A system of feeding that includes a legume or mixed hay of good quality and a balanced grain mixture containing bran and oilmeal or other high protein grains, will afford a liberal supply of calcium and phosphorus. Under such conditions of feeding, Nevens (16) showed that cows had practically no craving for inorganic mineral matter. He believes this to indicate that the supply of minerals in the ration was adequate. In contrast to this is the work of Eckles, et al. (14) in which cows were fed rations very low in mineral matter. These cows consumed large amounts of bone meal, especially at first, when they were allowed access to it, which would indicate that there was a craving for something not being supplied by the ration.

By placing emphasis on the feeding of proper rations as a prime requisite for supplying mineral matter, it is not meant that a mineral supplement such as steamed bone meal (much cheaper than dicalcium phosphate) should never be fed. It is so easy and relatively inexpensive thus to afford some protection against such extreme conditions as noted by Eckles and others that this means should not be overlooked in cases where it is felt that adequate rations are not being fed. Also, in cases of cows producing very heavily it may be well to feed a mineral supplement. However, such feeding should not be considered the equivalent of the use of proper roughages or grains.

SUMMARY AND CONCLUSIONS

Dicalcium phosphate was fed to one of two groups of cows over a period of 5 years and 11 months.

The total production of milk from the two groups averaged 30.54 pounds daily for the mineral group and 29.73 pounds daily for the non-mineral group.

The total production corrected to 4 per cent fat milk showed a daily production of 27.81 pounds per cow by the mineral group and 27.28 pounds per cow by the non-mineral group.

The daily production per cow during the first 7 months of the various lactation periods, corrected to 4 per cent fat, was by the mineral group 31.8 pounds and by the non-mineral group 33.33 pounds.

The daily production per cow during the first 7 months of lactation, corrected for quality of milk and for age of cow, was 37.3 pounds by the mineral group and 39.8 pounds by the non-mineral group.

Comparison of production in lactations before and after the experiment started showed an increase in both groups, but a greater increase by the non-mineral group.

Comparison of production in the first and second lactations of heifers during the experiment showed an increase in both groups, but a greater increase by the non-mineral group.

None of the above differences were large enough to be really significant when the probable error is considered.

Conceptions took place in the mineral group with sufficiently fewer services to be slightly significant.

Cases of abortion, sterility, and retained placenta occurred in both groups.

When rations containing legume hays and a grain mixture containing bran and linseed oilmeal or cottonseed meal are fed, cows probably will not be benefited by the addition of dicalcium phosphate.

In general, when rations of the above type are fed, mineral deficiencies probably do not exist.

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APPENDIX

TABLE 9.—Actual Milk Production by Lactations and Total and Average Daily Milk, Corrected to 4-per cent Fat

Cow No.	Age Yr.	In milk Days	Milk Lb.	Fat Lb.	Fat Per cent	F. C. M. per lactation Lb.	Av. daily F. C. M Lb.
Mineral group							
8	9	604	15,388	508	3.30	13,776	22.8
28	7	461	11,125	346	3.11	9,640	20.9
28	9	256	5,654	183	3.23	5,007	19.6
35	4	335	8,909	280	3.14	7,764	23.2
35	5	339	9,238	289	3.12	8,030	23.7
35	7	339	11,384	354	3.10	9,864	29.1
35	8	324	10,324	348	3.37	9,350	28.9
35	9	278	8,256	283	3.42	7,547	27.1
43	5	349	8,287	290	3.49	7,665	22.0
43	6	273	8,496	318	3.74	8,168	29.9
43	7	338	11,877	415	3.49	10,976	32.5
43	8	336	12,947	422	3.25	11,509	34.3
43	9	285	9,966	345	3.46	9,161	32.1
43	10	187	8,163*	288	3.52	7,585	40.6
45	5	318	8,763	280	3.19	7,705	24.2
45	6	330	10,463	353	3.37	9,480	28.7
45	7	384	11,531	362	3.13	10,042	26.2
46	5	388	9,472	329	3.47	8,724	22.5
46	6	276	9,307	310	3.33	8,373	30.3
46	7	308	11,309	375	3.31	10,149	33.0
46	8	317	8,918	294	3.29	7,977	25.2
46	9	394	14,195	461	3.24	12,593	32.0
46	10	206	9,608*	323	3.36	8,688	42.2
48	4	235	3,815*	144	3.77	3,686	15.7
48	5	303	6,050	243	4.01	6,065	20.0
48	6	251	6,567	249	3.79	6,362	25.3
50	2	442	8,180	281	3.43	7,487	16.9
50	3	275	7,089	249	3.51	6,571	23.9
50	4	611	15,361	514	3.34	13,854	22.7
52	2	424	13,987	456	3.26	12,435	29.3
52	3	372	14,286	474	3.31	12,824	34.5
52	4	322	14,047	490	3.48	12,969	40.3
52	5	484	18,389	620	3.37	16,656	34.4
52	6	75	4,535*	178	3.92	4,484	59.8
54	3	320	7,941	292	3.67	7,556	23.6
54	4	359	11,587	412	3.55	10,815	30.1
54	5	343	11,352	394	3.47	10,451	30.5
54	6	276	9,598	326	3.39	8,729	31.6
54	7	240	10,065	346	3.43	9,216	38.4
57	2	377	10,853	362	3.33	9,771	25.9
57	4	388	13,707	482	3.51	12,713	32.8
57	5	360	13,097	435	3.32	11,764	32.7
57	6	239	11,154	357	3.20	9,817	41.1
60	2	362	7,786	297	3.81	7,569	20.9
62	2	335	9,977	346	3.46	9,181	27.4
62	3	571	15,295	523	3.41	13,963	24.5
62	5	183	7,705*	246	3.19	6,772	37.0
64	2	555	14,715	505	3.43	13,461	24.3
66	2	313	7,423	249	3.35	6,704	21.4
70	2	399	12,372	490	3.96	12,299	30.8
Total		17,039	520,513	17,716		473,947	
Av. per lact.	5.4	340.8	10,410	354	3.40	9,479	
Av. daily per cow			30.54	1.039		27.81	

*Period does not contain first 7 months of experimental lactation.

TABLE 9.—Actual Milk Production by Lactations and Total and Average Daily Milk, Corrected to 4-per cent Fat—Continued

Cow No.	Age Yr.	In milk Days	Milk Lb.	Fat Lb.	Fat Per cent	F. C. M. per lactation Lb.	Av. daily F. C. M. Lb.
			Non-mineral group				
17	7	468	8,167*	291	3.56	7,632	16.3
17	9	435	10,466*	368	3.51	9,706	22.3
22	8	277	4,832	163	3.37	4,378	15.8
22	9	465	12,743	423	3.31	11,442	24.6
23	9	440	8,284	477	5.75	10,469	23.8
33	5	299	9,721	320	3.45	8,688	29.1
33	6	329	10,284	341	3.32	9,229	28.1
33	7	257	10,062	322	3.20	8,855	34.5
33	8	334	8,564	281	3.28	7,640	22.9
42	5	336	10,010	343	3.42	9,149	27.2
42	6	324	10,393	376	3.61	9,797	30.2
42	7	528	20,558	710	3.45	18,873	35.7
42	8	362	14,560	542	3.72	13,954	38.5
44	5	352	10,200	300	2.94	8,580	24.4
44	6	294	9,670	312	3.22	8,548	29.1
51	2	309	6,884	225	3.26	6,129	19.8
51	3	281	9,188	316	3.43	8,415	29.9
51	4	362	12,301	408	3.31	11,040	30.5
51	5	322	11,958	391	3.26	10,648	33.1
51	6	400	13,077	423	3.23	11,576	28.9
59	2	518	12,780	455	3.56	11,937	23.0
59	4	295	8,958	299	3.33	8,068	27.3
59	5	182	7,247*	275	3.79	7,024	38.6
61	2	347	10,721	393	3.66	10,183	29.3
61	3	471	16,366	556	3.39	14,886	31.6
61	5	267	12,578	422	3.35	11,361	42.6
63	2	414	9,791	326	3.32	8,806	21.3
63	3	277	10,019	319	3.18	8,793	31.7
65	2	686	15,538	503	3.23	13,760	20.1
65	4	220	9,073	307	3.38	8,234	37.4
67	2	314	8,086	282	3.48	7,464	23.8
69	2	469	12,839	472	3.67	12,216	26.0
Total 13 cows	.....	11,634	345,918	11,941	.....	317,480	.....
Av. per lact	5.03	363.5	10,810	373	3.45	9,921	.....
Av. daily per cow	.....	.....	29.73	1.026	.....	27.28	.....

*Period does not contain first 7 months of experimental lactation.

TABLE 10.—Average Milk Production Daily During the Frst 7 Months of Lactation. (Corrected for quality and age)

Mineral group				Non-mineral group			
Cow No.	Age	Milk produced	Corrected for age	Cow No.	Age	Milk produced	Corrected for age
	Yrs.	*Lb.*	*Lb.*		*Yrs.*	*Lb.*	*Lb.*
8	9	23.9	26.6	17	9	25.7	26.9
28	7	25.2	25.6	22	9	30.9	32.4
28	9	21.2	22.3	23	9	28.5	29.4
35	4	28.9	34.9	33	5	34.9	38.8
35	5	28.0	31.1	33	6	34.8	36.5
35	7	33.1	33.6	33	7	38.7	39.2
35	8	32.4	32.4	33	8	26.9	26.9
35	9	28.9	30.3	42	5	34.3	38.1
43	5	24.5	27.2	42	6	38.3	40.2
43	6	32.8	34.4	42	7	47.9	48.6
43	7	37.1	37.6	42	8	44.8	46.9
43	8	40.1	40.1	44	5	28.7	31.9
43	9	35.8	37.5	44	6	34.0	35.7
45	5	29.6	32.9	51	2	22.1	33.4
45	6	36.1	37.9	51	3	32.5	44.1
45	7	32.3	32.7	51	4	36.4	44.0
46	5	28.6	31.8	51	5	39.9	44.3
46	6	31.4	32.9	51	6	38.3	40.3
46	7	38.1	38.6	59	2	26.8	40.5
46	8	28.3	28.3	59	4	33.4	40.3
46	9	39.7	41.6	61	2	30.6	46.2
48	5	21.5	23.9	61	3	37.6	51.0
48	6	25.3	26.5	61	5	42.4	47.1
50	2	19.1	28.9	63	2	24.4	36.9
50	3	26.0	35.3	63	3	32.6	44.2
50	4	32.6	39.4	65	2	25.9	39.1
52	2	34.8	52.6	65	4	37.4	45.1
52	3	38.8	52.6	67	2	26.7	40.3
52	4	46.4	56.0	69	2	30.6	46.2
52	5	43.7	48.6				
54	3	27.6	37.4				
54	4	36.1	43.6				
54	5	34.3	38.1				
54	6	37.3	39.1				
54	7	36.5	37.0				
57	2	28.0	42.3				
57	4	42.1	50.8				
57	5	37.5	41.7				
57	6	39.7	41.7				
60	2	21.5	32.5				
62	2	28.5	42.9				
62	3	33.8	45.9				
64	2	29.1	44.0				
66	2	23.3	35.1				
70	2	33.6	50.8				
Average daily per cow		31.8	37.3±0.801			33.3	39.8±0.782
Average age	5.2				4.9		

TABLE 11.—Average Daily Milk Production During Frst 7 Months of Lactations (F. C. M.) Mature-age Basis

Cow No.	Before the experiment Milk Lb.	During the experiment Milk Lb.	Increase or decrease Lb.
Mineral group			
8	28.3	26.6	1.7
28	25.0	25.6	0.6
35	22.9	34.9	12.0
43	25.0	27.2	2.2
45	29.1	32.9	3.8
46	28.6	31.8	3.2
Average	26.5	29.8	3.3
Per cent increase			12.45
Non-mineral group			
17	18.6	26.9	8.3
22	20.6	32.4	11.8
23	24.1	29.4	5.3
33	27.8	38.8	11.0
42	37.3	38.1	0.8
44	33.6	31.9	—1.7
Average	27.0	32.9	5.9
Per cent increase			21.85

TABLE 12.—Average Daily Production of Heifers in First 7 Months of First and Second Lactations

Cow	1st lactation 4 per cent milk Lb.	2nd lactation 4 per cent milk Lb.	Increase Lb.
Mineral group			
50*	19.1	26.0	6.9
52†	34.8	38.8	4.0
54†	27.6	36.1	8.5
57†	28.0	42.1	14.1
62†	28.4	33.8	5.4
Average	27.6	35.3	7.7
Per cent increase			27.9
Non-mineral group			
51*	22.1	32.5	10.4
59†	26.8	33.4	6.6
61†	30.6	37.6	7.0
63†	24.4	32.6	8.2
65†	25.9	37.4	11.5
Average	26.0	34.7	8.7
Per cent increase			33.5

*Sired by Wooster Hengerveld De Kol.
†Sired by De Kol Hydekoper.

TABLE 13.—Length of Lactation, Days Dry, and Services per Calf

Mineral group				Non-mineral group			
Cow No.	Days in milk	Days dry	Services per calf	Cow No.	Days in milk	Days dry	Services per calf
28	461	19	2	17	650	75	4
35	335	27	1	17	435	41	3
35	339	119	1	22	449	65	2
35	339	94	3	23	440	56	3
35	324	81	1	33	299	54	1
43	349	92	2	33	329	88	1
43	273	85	1	33	334	92	1
43	338	30	1	42	336	10	2
43	336	93	2	42	324	56	1
43	285	88	1	42	528	44	6
45	318	61	1	44	352	75	1
45	330	45	3	44	294	85	3
46	388	45	2	51	309	37	1
46	276	37	1	51	281	28	1
46	317	80	1	51	362	37	1
46	394	91	2	51	322	36	1
48	303	21	1	59	518	46	3
50	442	22	1	59	295	101	1
50	275	42	1	61	347	42	1
50	611	34	3	61	471	44	3
52	424	22	2	63	414	64	3
52	372	30	1	65	686	49	4
52	322	25	1				
52	484	42	1				
54	320	47	1				
54	359	20	2				
54	343	106	3				
54	276	35	1				
57	377	57	2				
57	388	26	1				
57	360	36	1				
60	362	10	2				
62	335	37	1				
62	571	34	2				
Total	12,326	1,733	52	Total	8,775	1,225	47
Average	363	51	1.53	Average	399	55.6	2.13